EXTREME HEAT

Deforestation intensifies hot days

Deforestation often increases land-surface and near-surface temperatures, but climate models struggle to simulate this effect. Research now shows that deforestation has increased the severity of extreme heat in temperate regions of North America and Europe. This points to opportunities to mitigate extreme heat.

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Extreme heat is dangerous. Crops fail, wildlife suffers and people, especially the disadvantaged, die[1]. The number of extremely hot days is expected to continue to increase, placing a greater burden on ecological and social systems. Limiting the concentration of greenhouse gases in the atmosphere is of course the best way to mitigate extreme high temperatures globally. But are there other ways to turn down the heat?

Writing in *Nature Climate Change*, Lejeune and colleagues[2] show one such possibility: forests can help mitigate extreme heat. Specifically, Lejeune et al. find that deforestation during the industrial era in the northern mid-latitudes has increased the intensity of hot days. To arrive at this conclusion, they noted that deforested areas in temperate regions of North America and Europe tend to be hotter than adjacent forests, especially during extreme heat events[3]. Some Coupled Model Intercomparison Project Phase 5 (CMIP5) climate models[4] simulated the direction of this effect correctly; others did not. Those that did showed an average maximum annual temperature increase of 0.1 °C for a 10% decrease in tree cover. This is some three to six times smaller than the observed effect of deforestation on maximum temperatures in temperate, boreal and arid regions[5], but it is a step in the right direction with regards to constraining the effects of forest cover on extreme heat in climate models.

Climate extremes continue to elude models, which are often parameterized to match mean conditions despite the disproportionate importance of extremes. As a starting point, models need to correctly simulate the combined biogeophysical and biogeochemical impacts of land cover and its changes. In most CMIP5 models, deforestation in temperate ecosystems has a cooling effect because less radiation is absorbed by the brighter land surface: an increase in shortwave albedo. Albedo is important, but there are other mechanisms at play, and we need to understand their impacts across different biomes to understand the role of vegetation in the climate system.

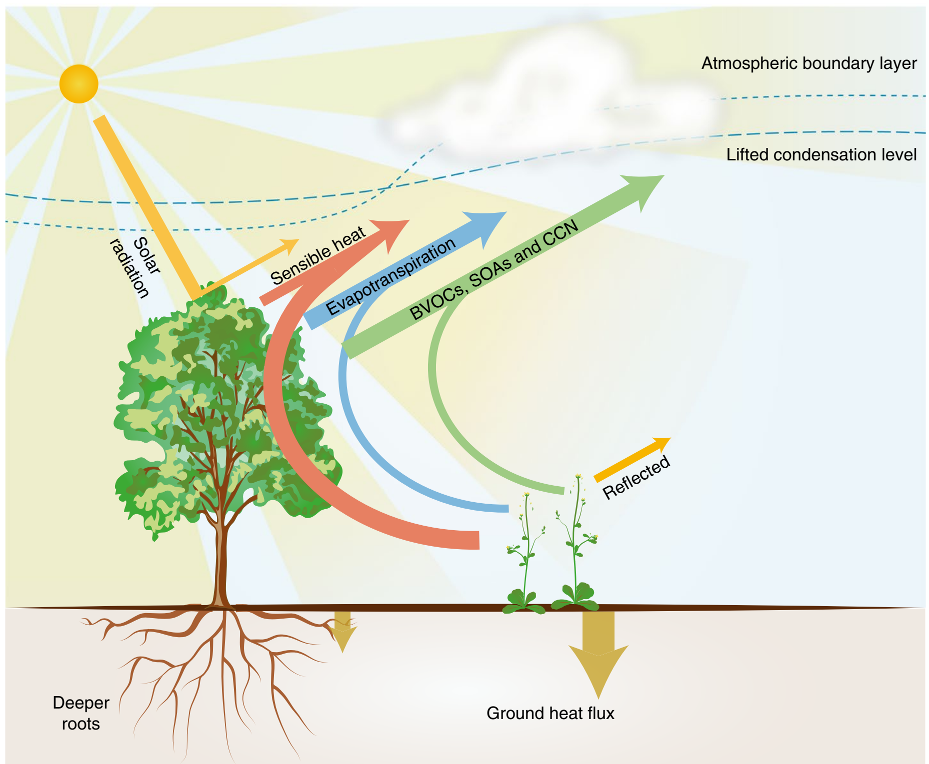

Fig. 1 | Schematic of the impacts of deforestation on surface and near-surface temperature extremes. Forests reflect less solar radiation, but tend to have greater evaporative cooling as drought progresses[7] through differences in rooting depth and plant–water relations. Forests also tend to produce more of the biogenic volatile organic compounds (BVOCs) that are precursors to secondary organic aerosols (SOAs), which absorb and scatter solar radiation. SOAs can aggregate to form cloud condensation nuclei (CCN) and thus enhance cloud formation. Sensible heat flux and evapotranspiration also impact cloud development by determining the height of the atmospheric boundary layer and if it crosses the lifted condensation level at which condensation occurs. Forests also have higher surface roughness than deforested areas, which reduces the resistance of sensible and latent heat transport between the land surface and the atmosphere. Please note that the figure is not to scale.

Deforestation is thought to cool boreal ecosystems because the cooling effect of higher albedo — especially in the presence of snow cover — outweighs warming from reductions in evaporative cooling[6,7]. The opposite case holds for tropical ecosystems, where deforestation results in net land surface warming because the reduction in evaporative cooling outweighs the cooling effects of higher albedo[7]. Temperate ecosystems, despite being arguably the best-studied of all global ecosystems, fall somewhere in between[7] and their aggregate impacts on climate are less certain. But extremes are important, and Lejeune et al. demonstrate that temperate forests are critical players in regional extreme temperature events.

The tendency of temperate forests to dampen extreme heat should be seen in terms of climate services. To fully realize the benefits of these services, we need to understand how they work. One way that forests reduce extreme surface heat is by maintaining evaporation for longer periods during drought by accessing water with deep roots (Fig. 1), by controlling transpiration at the leaf level, or both. Such differences in ecosystem hydrology caused forests to be cooler during the peak of the 2003 European summer heat wave[8]. Deforested areas had a cooling effect during the earlier stages of this drought because evapotranspiration increased: a water-spending anisohydric strategy. This initial evaporative cooling depleted soil water reserves, and deforested areas consequently became hotter as the drought progressed. Forests on the other hand were able to maintain evaporative cooling for a longer period[8] because they used water more sparingly — an isohydric strategy — early during the drought. As a result, forests were initially warmer than deforested areas. But by saving water early, forests were able to conserve soil moisture and provide a cooling service through evapotranspiration as the drought progressed and became more extreme.

Water use is one of many ways by which forests regulate regional climate and its extremes. Biogenic volatile organic compounds emitted by vegetation — especially forests — contribute to organic aerosol production, which scatters and absorbs solar radiation. These aerosols can aggregate to form cloud condensation nuclei and thus enhance cloud development (Fig. 1). Aerosol production is accelerated under hot temperatures and acts as a negative feedback to extreme daytime heat in the continental mid-latitudes[9]. Vegetation also influences cloud development by controlling the amount of heat and moisture that enters the atmospheric boundary layer. Air parcels receive heat and moisture from the land surface and become buoyant and, if they have sufficient convective energy, can rise to the layer of the atmosphere where they condense to form clouds, the lifted condensation level. In doing so, vegetation creates another mechanism by which the burden of extreme daytime temperatures is lessened[10] (Fig. 1). Forests also have a lower resistance to heat and moisture transport between the surface and the atmosphere due to greater surface roughness, which is another major pathway by which temperate forests remain (relatively) cool during the day[11].

It is important to note that deforestation and reforestation are not the only vegetation changes that impact regional climate. Different trees within forests and different crops within fields adopt varying water use, rooting and volatile emission strategies that influence the physics and chemistry of the land surface and atmospheric boundary layer[12]. All of these factors influence regional climate and extreme heat in ways that remain poorly understood. Regardless, the lessons from Lejeune et al.[2] still hold: past deforestation made extreme heat worse in critical regions of the globe. Now we need to understand the mechanisms by which vegetation impacts temperature extremes globally, and use this understanding to become wiser stewards of the Earth system. ❐

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Competing interests

The author declares no competing interests.